Timing of Fast Scintillators using Digitizers

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Introduction

Recently, FPGA based digitizers have found attractive applications in signal processing for complex detector arrays in nuclear physics [1]. In the fast digitizers, a flash ADC directly samples and stores the PMT output of scintillation detectors. Digital Signal Processing (DSP) techniques are used to extract the energy and timing information of the acquired signal. DSP not only reduces requirement of electronics units and cabling, but also eliminates temperature related drifts to a large extent. The jitter and walk introduced by the discriminator in an analog chain can be avoided by using digital timing techniques.

This paper presents the time resolution studies of fast scintillators using digital constant fraction discrimination (CFD) method. Detector pulse waveforms are acquired using CAEN make digitizers with sampling frequency of 1 GHz (i.e. 1GS/s) and 250 MHz [2]. An offline algorithm for digital CFD has been developed in a MATLAB platform. This algorithm was also tested to study time structure of the pulsed ^{28}Si beam (E=88 MeV) at Pelletron LINAC Facility (PLF), Mumbai.

Experimental Details and Analysis

In the present study three types of fast scintillators, namely, BaF_2 (Φ 2”x2” with Philips XP2020/Q PMT), $CeBr_3$ (Φ 1.5”x1.5” with Hamamatsu R6231 PMT) and $LaBr_3$(Ce)-NaI(Tl) phoswich (PARIS cluster element [3] coupled to Hamamatsu R7723 PMT) were used. In order to study time response of each scintillator, measurements were carried out with a ^{60}Co source sandwiched between two identical detectors. For waveform sampling, commercially available digitizers CAEN V1751/N6751 (1 GS/s, 10 bit, 1 Vpp) and V1720/N6720 (250 MS/s, 12 bit, 2 Vpp) with in-built standard firmware and wavedump software for recording pulses were used. In each measurement set, the PMT anode output of both scintillators was directly connected to the digitizer inputs. When either of the detector signal is present, internal trigger of the digitizer is activated and waveforms from both the channels are saved to the buffer. Since waveforms from both channels are in the same time window, offline timing analysis can be carried out. The width of the time window is configurable in terms of number of samples.

The acquired waveforms were processed by an offline digital constant fraction zero-crossing algorithm developed in MATLAB platform. Since the trigger can be generated from either of the channels, the algorithm first detects the presence of the pulse in a given channel. The baseline is calculated and subtracted from the raw waveform so that constant fraction zero crossing can be implemented. The attenuated pulse is added with delayed inverted to produce the bipolar signal as shown in Fig. 1. The zero crossing time of the bipolar signal is determined by linear interpolation between two points where zero crossing occurs. Time spectra are constructed using the difference in the interpolated time between two detector channels.

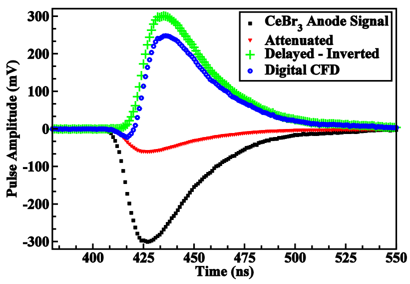

Figure 1: Digital constant fraction zero crossing of a $CeBr_3$ signal with a sampling rate of 1 GS/s.

Further, energy gate (1.17 MeV, 1.33 MeV) was added for removing the random coincidences, which also eliminated low threshold events.

Figures 2-4 show the time spectra generated for different detectors at 250 MS/s and 1 GS/s sampling rates together with Gaussian fits. The CFD parameters and FWHM of time spectra for different detectors are given in Table 1. In each case, the CFD delay parameter is kept comparable to the rise time of the detector. It is clear that for these fast detectors, 1GS/s gives better results.

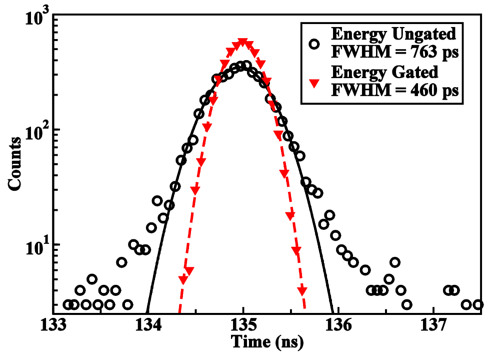

Figure 2: Time spectra for phoswich detectors with and without energy gate (1GS/s digitizer).

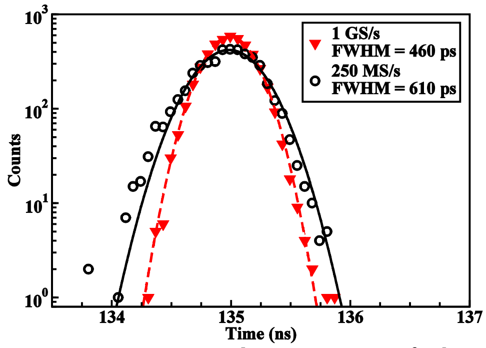

Figure 3: Energy gated time spectra of phoswich detectors with 1 GS/s and 250 MS/s digitizers.

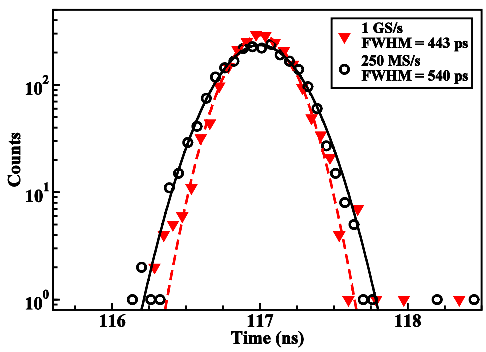

Figure 4: Same as Fig.3 for $CeBr_3$ detectors.

Table 1: Summary of Digital CFD parameters and time resolution obtained for different scintillators

Detector	Rise time (ns)	Sampling rate	CFD Parameters Fraction (%)	CFD Parameters Delay (ns)	FWHM (ps)	FWTM (ps)
BaF_2	3	1 GS/s	20	3	466	849
PARIS phoswich	9	1 GS/s	20	6	460	838
		250 MS/s	33	12	610	1112
$CeBr_3$	12	1 GS/s	20	10	443	807
		250 MS/s	40	12	540	984

The time structure of the pulsed ^{28}Si beam (E=88 MeV) at Pelletron LINAC Facility (PLF), Mumbai was studied using 1 GS/s digitizer with the $CeBr_3$ detector. Figure 5 shows the time spectrum w.r.t. the sweeper RF, generated with offline CFD together with that recorded using the analog electronics. It can be clearly seen from the figure that both spectra are in good agreement.

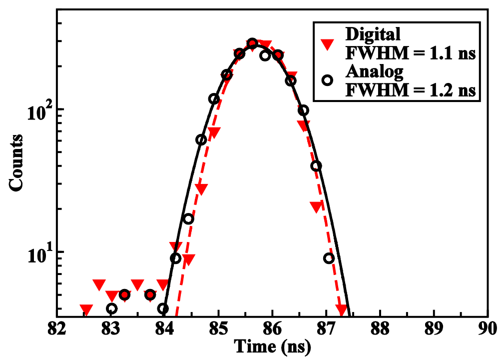

Figure 5: Time spectrum of the pulsed ^{28}Si beam with $CeBr_3$ detector w.r.t. the sweeper RF.

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References

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